VIII. *Continuation of a former Paper on the Twenty-five Feet Zenith Telescope lately erected at the Royal Observatory. By* JOHN POND, *Esq. A.R. F.R.S.*

Received March 11,—Read March 12, 1835.

DURING the last summer I had the honour of submitting to this Society a short paper on the subject of the large zenith telescope lately erected at this Observatory.

It is now nearly twenty years since the erection of such an instrument was first suggested to the President and Council of this Society; at that time the Royal Observatory was in a very inefficient state compared to what it is at present. We had only one circle; and there existed doubts as to the excellence of this instrument, though not any were ever entertained by me. The erection of a second circle put this question at rest; it has been abundantly shown in various volumes of the Greenwich Observations, by a series of more rigorous investigations than any instrument was ever submitted to before, that both the circles may be considered as perfect, their errors being less than their respective makers themselves assigned.

This circumstance, though satisfactory to myself, a little diminished the importance of the new zenith telescope. It was hardly to be expected that any new instrument could throw light upon errors already reduced within such small limits; this, however, has been done, and the object of this paper is to explain the process I have employed for the purpose.

Whoever is acquainted with the method of constructing the Greenwich Catalogue, must have perceived that the places of those stars which are observed by reflection are, according to all probability, more exactly determined than those which have been observed only by direct vision. γ Draconis, a star which since the time of BRADLEY has been of first-rate importance in the Greenwich Observations, cannot be observed by reflection. The probability of error was therefore greater in the place of this star than in that of any other. The new instrument has shown that this error does not exceed a quarter of a second; a degree of accuracy scarcely credible, and no doubt requiring to be confirmed by future observations.

The nature of the question to be determined in this case has happily produced a competition for excellence among the observers with the different instruments, which gives me an opportunity of showing the present state of practical astronomy at Greenwich.

The new instrument has been employed during the last summer under very unfavourable circumstances, both the building and the instrument having been almost constantly under repair. It is not requisite on this occasion to enter into the details

of these difficulties; I only wish to explain the nature of the experiments, the results of which I am now about to lay before the Society.

We have now three distinct methods of determining the place of any star passing the meridian near the zenith. First, by means of the mural circles; secondly, by the zenith telescope used alternately east and west, as is usually done with similar instruments; and lastly, by means of a small subsidiary star, as described by me last year in a paper laid before this Society, and which I am inclined to think more exact than any other method. By the following computations it will be seen that the three methods give results nearly identical; and that when the observations with the two circles are numerous and made with sufficient care, a quarter of a second is the greatest error to be apprehended.

Royal Observatory, March 10, 1835.

Results of Observations on γ Draconis and Bode 170 *Draconis.*

Zenith distance of γ Draconis determined by three different methods.

	Zenith distance, 1834.
First,—Result by 324 observations with the Mural Circles reduced to the latitude of the Zenith Telescope room, the difference between which and the Circle room being 0″·65 North	2′ 1″·36 North.
By Zenith Telescope employed in the unsual manner by alternate observations East and West; 28 results	2 1·11
By means of the subsidiary angle as described in my former paper of last year, and which result I prefer to either of the others	2 1·09

Zenith distance of Bode 170 Draconis determined by three different methods.

	Zenith distance, 1834.
First,—Result by 132 observations with the Mural Circles reduced to the latitude of the Zenith Telescope room, the difference between which and the Circle room being 0″·65 North	1′ 0″·45 South.
By Zenith Telescope employed in the usual manner by alternate observations East and West; 14 results	1 0·61
By means of the subsidiary angle as described in my former paper of last year, and which result I prefer to either of the others	1 0·74

Table I.

Containing 60 successive observations of the small auxiliary star, Bode 170 Draconis, divided into series of 10 each.

1833.	Bode 170 Draconis, by Jones's Circle. N. P. D. Jan. 1, 1834.	Diff. of each Obs. from Mean of 60.	Diff. between the Mean of 10 and the Mean of 60.	1834.	Bode 170 Draconis, by Jones's Circle. N. P. D. Jan. 1, 1834.	Diff. of each Obs. from Mean of 60.	Diff. between the Mean of 10 and the Mean of 60.
	° ′ ″	″			° ′ ″	″	
July 22.	38 32 20·68	0·40		July 8.	38 32 21·40	0·32	
23.	21·62	0·54		9.	21·00	0·08	
25.	20·83	0·25		10.	20·68	0·40	
26.	21·70	0·62		11.	21·08	0·00	
27.	21·25	0·17		12.	21·39	0·31	
29.	21·87	0·79		14.	20·99	0·09	
31.	21·73	0·65		15.	20·48	0·60	
Aug. 1.	21·79	0·71		16.	20·97	0·11	
3.	22·17	1·09		17.	20·77	0·31	
4.	21·81	0·73		21.	20·39	0·69	
Mean of 10 obs.	38 32 21·55		0·47	Mean of 10 obs.	38 32 20·92		0·16
6.	21·70	0·62		22.	21·07	0·01	
9.	21·57	0·49		24.	21·84	0·76	
11.	21·09	0·01		25.	20·11	0·97	
13.	20·91	0·17		30.	20·92	0·16	
14.	20·50	0·58		Aug. 1.	20·42	0·66	
16.	20·65	0·43		2.	21·68	0·60	
23.	20·79	0·29		6.	21·24	0·16	
25.	21·20	0·12		11.	21·02	0·06	
26.	20·85	0·23		12.	20·14	0·94	
27.	20·43	0·65		16.	20·86	0·22	
Mean of 10 obs.	38 32 20·97		0·11	Mean of 10 obs.	38 32 20·93		0·15
28.	21·07	0·01		19.	20·63	0·45	
Sept. 1.	20·82	0·26		22.	21·57	0·49	
3.	20·86	0·22		23.	21·36	0·28	
4.	20·86	0·22		25.	20·76	0·32	
5.	21·13	0·05		27.	21·18	0·10	
6.	21·36	0·28		Sept. 4.	20·89	0·19	
12.	21·31	0·23		5.	21·19	0·11	
18.	21·07	0·01		12.	21·21	0·13	
20.	20·95	0·13		13.	21·38	0·30	
23.	20·92	0·16		15.	20·58	0·50	
Mean of 10 obs.	38 32 21·04		0·04	Mean of 10 obs.	38 32 21·08		0·00
Mean of 60 obs. . . . . =					38 32 21·08	0·357	0·155

From this it appears that the mean error of 10 observations = 0″·155, and that the mean error of 30 observations, as deduced from the next page, = 0″·067.

The zenith distance from this result	=	1′ 0″·078 South. (Assumed co-latitude = 38° 31′ 21″*.)
Difference of latitude for zenith telescope	=	+0·65
Zenith distance for the latitude of zenith telescope	=	1 0·728
By zenith telescope by means of the subsidiary angle from the preceding page . .	=	1 0·74, which two quantities are identical.

* The accuracy of this quantity is of no importance, as the circles, according to our present mode of employing them, give, in fact, zenith distances, which are afterwards converted into polar distances by the application of the above co-latitude, and as such are registered in the Greenwich Catalogues.

Table II.

The same observations of Bode 170 Draconis arranged alternately in two columns of 30 observations each.

	N. P. D. Jan. 1, 1834.		N. P. D. Jan. 1, 1834.
1833. July 22.	° ′ ″ 38 32 20·68	1833. July 23.	° ′ ″ 38 32 21·62
25.	20·83	26.	21·70
27.	21·25	29.	21·87
31.	21·73	Aug. 1.	21·79
Aug. 3.	22·17	4.	21·81
6.	21·70	9.	21·57
11.	21·09	13.	20·91
14.	20·50	16.	20·65
23.	20·79	25.	21·20
26.	20·85	27.	20·43
Mean of 10 obs.	38 32 21·159	Mean of 10 obs.	38 32 21·355
Aug. 28.	38 32 21·07	Sept. 1.	38 32 20·82
Sept. 3.	20·86	4.	20·86
5.	21·13	6.	21·36
12.	21·31	18.	21·07
20.	20·95	23.	20·92
1834. July 8.	21·40	1834. July 9.	21·00
10.	20·68	11.	21·08
12.	21·39	14.	20·99
15.	20·48	16.	20·97
17.	20·77	21.	20·39
Mean of 10 obs.	38 32 21·004	Mean of 10 obs.	38 32 20·946
July 22.	38 32 21·07	July 24.	38 32 21·84
25.	20·11	30.	20·92
Aug. 1.	20·42	Aug. 2.	21·68
6.	21·24	11.	21·02
12.	20·14	16.	20·86
19.	20·63	22.	21·57
23.	21·36	25.	20·76
27.	21·18	Sept. 4.	20·89
Sept. 5.	21·19	12.	21·21
13.	22·38	15.	20·58
Mean of 10 obs.	38 32 20·872	Mean of 10 obs.	38 32 21·133
Mean of 30 =	38 32 21·012	Mean of 30 =	38 32 21·145
Mean of 60 = 38° 32′ 21″·08.			

Table III.

Difference of North Polar Distance of γ Draconis and Bode 170 Draconis, 1833.

1833.	Observed Difference. Troughton.	Observed Difference. Jones.	Difference of Equations.	Difference, January 1, 1833. Troughton.	Difference, January 1, 1833. Jones.
	′ ″	′ ″	″	′ ″	′ ″
July 5.	3 6·2	3 5·4	−1·36	3 4·84	3 4·04
6.	5·3	6·7	−1·35	3·95	5·35
9.	6·0	4·9	−1·31	4·69	3·59
15.	5·5	5·5	−1·18	4·32	4·32
16.	5·9	5·7	−1·15	4·75	4·55
22.	4·8	5·3	−1·04	3·76	4·26
23.	4·5	5·9	−1·01	3·49	4·89
25.	5·1	5·4	−0·98	4·12	4·42
26.	6·0	5·6	−0·95	5·05	4·65
27.	5·7	5·6	−0·94	4·76	4·66
29.	4·9	5·9	−0·89	4·01	5·01
31.	4·6	4·0	−0·84	3·76	3·16
August 1.	3·8	4·7	−0·81	2·99	3·89
3.	4·8	4·9	−0·77	4·03	4·13
4.	6·0	5·2	−0·74	5·26	4·46
6.	4·8	4·0	−0·69	4·11	3·31
9.	5·1	4·8	−0·61	4·49	4·19
11.	2·9	4·7	−0·56	2·34	4·14
13.	3·6	5·4	−0·50	3·10	4·90
14.	4·1	4·6	−0·47	3·63	4·13
16.	3·0	4·3	−0·42	2·58	3·88
23.	3·7	4·6	−0·19	3·51	4·41
25.	3·6	3·9	−0·13	3·47	3·77
26.	3·9	4·2	−0·09	3·81	4·11
27.	4·5	4·4	−0·06	4·44	4·34
28.	4·7	4·7	−0·04	4·66	4·66
Sept. 1.	3·0	3·6	+0·10	3·10	3·70
3.	1·6	3·7	+0·16	1·76	3·86
4.	3·6	3·9	+0·19	3·79	4·09
5.	2·8	3·7	+0·23	3·03	3·93
6.	3·5	4·3	+0·26	3·76	4·56
12.	2·7	3·9	+0·43	3·13	4·33
18.	2·8	3·0	+0·67	3·47	3·67
20.	2·6	3·7	+0·75	3·35	4·45
23.	3·1	3·3	+0·86	3·96	4·16
Mean of 35 obs. =				3 3·807	3 4·228
Mean of 70 obs. ...... =				3′ 4″·018	

Difference of North Polar Distance of γ Draconis and Bode 170 Draconis, 1834.

1834.	Observed Difference. Troughton.	Observed Difference. Jones.	Difference of Equations.	Difference, January 1, 1834. Troughton.	Difference, January 1, 1834. Jones.
	′ ″	′ ″	″	′ ″	′ ″
July 8.	3 1·4	3 3·6	−1·31	3 0·09	3 2·29
9.	3·6	4·2	−1·30	2·30	2·90
10.	3·5	3·3	−1·28	2·22	2·02
11.	3·7	3·0	−1·27	2·43	1·76
12.	3·1	3·0	−1·24	1·86	1·76
14.	2·7	2·4	−1·21	1·49	1·19
15.	3·3	3·0	−1·20	2·10	1·80
16.	1·9	3·8	−1·19	0·71	2·61
17.	3·8	2·4	−1·17	2·63	1·23
21.	2·7	2·1	−1·08	1·62	1·02
22.	4·3	3·0	−1·04	3·26	1·96
24.	3·3	3·6	−1·01	2·29	2·59
25.	3·2	2·6	−0·98	2·22	1·62
30.	3·2	3·1	−0·86	2·34	2·24
August 2.	2·3	3·4	−0·84	1·46	1·96
6.	2·3	1·8	−0·71	1·59	0·21
11.	3·6	2·6	−0·55	3·05	2·05
12.	2·4	1·3	−0·52	1·88	0·78
16.	2·5	1·0	−0·43	2·07	0·57
19.	3·1	1·6	−0·32	2·78	1·28
22.	2·0	2·3	−0·24	1·76	2·06
23.	2·0	3·0	−0·21	1·79	2·79
25.	1·4	2·0	−0·15	1·25	1·86
27.	2·3	2·1	−0·08	2·22	2·02
Sept. 5.	1·0	1·9	+0·24	1·24	2·14
12.	1·4	1·7	+0·45	1·85	2·15
13.	1·1	2·7	+0·49	1·59	3·19
15.	1·3	0·4	+0·57	1·87	1·97
16.	0·8	1·2	+0·60	1·40	1·80
Mean of 29 obs. =				3 1·901	3 1·854
Mean of 58 obs. .... =				3′ 1″·877	

		′	″
Mean of 70 obs. (= 35 × 2) with both circles for the epoch Jan. 1, 1833, as above	=	3	4·018
Sum of Annual Variations of both stars	= −		2·240
Difference of North Polar Distance reduced to Jan. 1, 1834, by 70 obs. in 1833 ..	=	3	1·778
Mean of 58 obs. (= 29 × 2) for Jan. 1, 1834, by 58 obs. in 1834	=	3	1·877
Mean of total 128 obs. Jan. 1, 1834	=	3	1·823

TABLE IV.

Fundamental determinations of the Zenith Distances of γ Draconis.

Epochs.	State of lunar nutation.	Observed zenith dist. reduced to the beginning of each year.	Side of zen.	Zenith distance deduced from M. BESSEL's Formula (TABULÆ REGIOMONTANÆ, p. 46.).				Difference of formula and observed zen. dist.	
				Epochs. 1800.	1st term.	2nd term.	Resulting Z. D.		
1753.	$-6''\cdot87$	$3'\ 2''\cdot05$	N.	$2'\ 26''\cdot669$	$+33''\cdot555$	$+2''\cdot233$	$3'\ 2''\cdot457$	$+0''\cdot407$	By BRADLEY with Zen. Sector.
1768.	$+3\cdot83$	$2\ 50\cdot30$	..	$2\ 26\cdot669$	$+22\cdot899$	$+1\cdot035$	$2\ 50\cdot603$	$+0\cdot303$	MASKELYNE Ditto.
1802.	$+9\cdot52$	$2\ 25\cdot30$	..	$2\ 26\cdot669$	$-\ 1\cdot428$	$+0\cdot004$	$2\ 25\cdot245$	$-0\cdot055$	Ditto. Ditto.
1813.	$-7\cdot64$	$2\ 17\cdot40$	..	$2\ 26\cdot669$	$-\ 9\cdot281$	$+0\cdot171$	$2\ 17\cdot559$	$+0\cdot159$	POND Ditto.
1833.	$-4\cdot30$	$2\ \ 2\cdot47$	..	$2\ 26\cdot669$	$-23\cdot560$	$+1\cdot101$	$2\ \ 4\cdot210$	$+1\cdot740$	Ditto New Zen. Telescope.

The above results (column 3rd) are those that have been obtained with the greatest care during their respective periods; and having been deduced from observations with the zenith sector, they are quite independent of the latitude of the Observatory.

M. BESSEL's formula is deduced from the observations for the first sixty years, and therefore agree very well; but when we attempt to predict from the observations of these sixty years the place of the stars for twenty years to come, we find a difference of $1''\cdot74$ between the predicted and observed zenith distance, the observed place being this quantity south of it.

Explanation of the foregoing TABLES.

Table I. contains the results of 60 observations of the small star Bode 170 Draconis, made with JONES's circle, and is intended to show what degree of accuracy may be obtained by extreme care. The mean difference $0''\cdot357$, column 3, between the mean of the whole and each result, (and which is nearly the probable error of a single observation from this series,) demonstrates with what care they have been made. The same may be said with respect to the mean difference of column 4, namely, $0''\cdot155$, which is similarly obtained from the mean of the whole and the mean of each ten (a quantity which represents nearly the probable error of the mean of ten observations). However, it may be remarked, that the exact coincidence exhibited throughout this series does not prove the truth of the final north polar distance of the star here assigned, since some omissions or errors in the process of reduction would affect it. That no instrumental error exists is demonstrated by the identity of the result with that obtained with the new instrument.

Table II. contains the same observations arranged in a different manner.

This is the arrangement I have advantageously followed in investigating the difference of parallax; the object being to distinguish the effect arising from accidental error of observation from that which is due to any permanent astronomical cause.

This method should be employed when the object is to judge of the consistency of observations, without any reference to the astronomical result.

Table III. shows the manner in which the difference in zenith distance between the two stars is obtained by means of the circles; a quantity, as I have shown, of the highest importance in the investigation.

This quantity, having been determined by the microscopes of the respective circles, might be erroneous if the runs of the microscopes were not exact, although the error here must be very small, twelve microscopes being constantly used. But as they have lately been taken down, examined, and replaced, without any sensible alteration, it may be presumed that the error from this source is sufficiently corrected.

Table IV. This Table contains in a very compressed form the result of an immense number of observations of γ Draconis during a period of eighty years; and it will be seen that if from M. Bessel's formula*, deduced from the first sixty years of these observations, we attempt to predict or assign the place of the star for the present time or twenty years in advance, the star will be found $1''{\cdot}75$ south of its computed place.

* By this formula the zenith distance of the star north for 1800, $+ t = 2' \, 26''{\cdot}669 - t \, . \, 0''{\cdot}71394 + t^2 \, . \, 0''{\cdot}001011$. Where t is the number of years before or after 1800, if before, the sign of t is minus.